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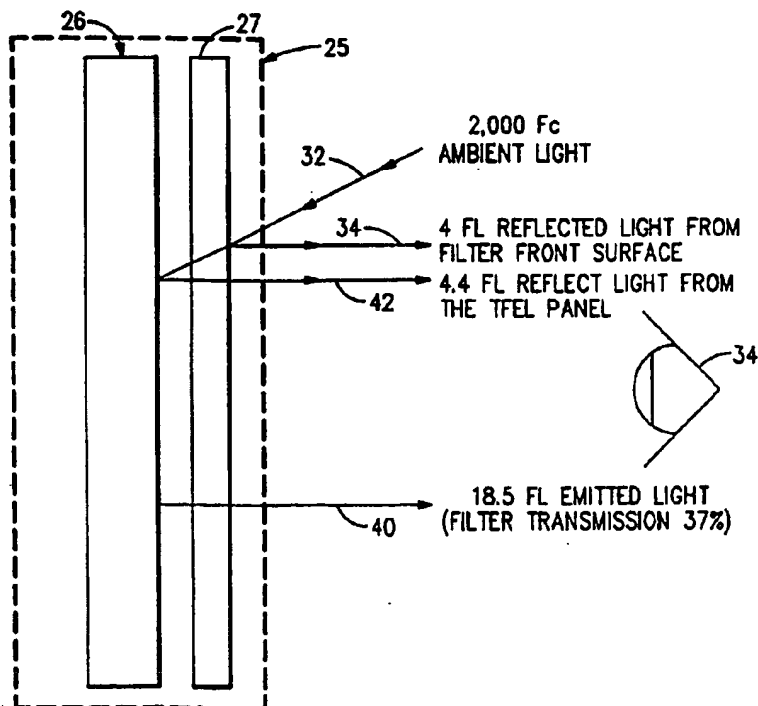
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(21) International Application Number: PCT/US93/12233 (22) International Filing Date: 15 December 1993 (15.12.93) (30) Priority Data: 997,271 23 December 1992 (23.12.92) US (71) Applicant: UNITED TECHNOLOGIES CORPORATION [US/US]; United Technologies Building, Hartford, CT 06101 (US). (72) Inventors: BUDZILEK, Russell, A.; 417 Lake Avenue, Bridgeport, CT 06605 (US). MONARCHIE, Dominick, L.; 5, Wayfaring Road, Norwalk, CT 06851 (US). PODOBA, Myroslaw; 87 High Hill Road, Wallingford, CT 06492 (US). SWATSON, Richard, R.; 21 Hedgehog Road, Trumbull, CT 06611 (US). (74) Agent: O'SHEA, Patrick, J.; United Technologies Corporation, Patent Department, United Technologies Building, Hartford, CT 06101 (US).		(81) Designated States: CA, JP, KR, RU, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published With international search report.

(54) Title: HIGH CONTRAST THIN FILM ELECTROLUMINESCENT DISPLAY



**(57) Abstract**

A display system (25) includes an enhanced specularity multi-layer thin film electroluminescent (TFEL) panel (26) and circular polarizer filter (27) which combine to provide a high contrast TFEL display. The enhanced specularity is obtained by increasing the rate the phosphor layer of the panel is deposited which results in a smoother, more specular surface. The increased specularity of the panel (26) provides a darker display background, and therefore higher contrast.

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## Description

HIGH CONTRAST THIN FILM  
ELECTROLUMINESCENT DISPLAY

## Technical Field

5           This invention relates to electroluminescent display panels and more particularly to high contrast high specularity electroluminescent display panels.

## Background Art

10           Thin film electroluminescent (TFEL) display panels offer several advantages over older display technologies such as cathode ray tubes (CRTs) and liquid crystal displays (LCDs). Compared with CRTs, TFEL display panels require less power, provide a larger viewing angle, and are much thinner. Compared  
15           with LCDs, TFEL display panels have a larger viewing angle, do not require auxiliary lighting, and can have

          Fig. 1 shows a conventional TFEL panel 10. The TFEL panel has a glass panel 11, a plurality of transparent electrodes 12, a first layer of a  
20           dielectric 13, a phosphor layer 14, a second dielectric layer 15, and a plurality of metal rear electrodes 16 perpendicular to the transparent electrodes 12. The transparent electrodes 12 are typically indium-tin oxide (ITO) and the metal electrodes 16 are typically  
25           Al. The dielectric layers 13,15 to protect the phosphor layer 14 from excessive dc currents. When an electrical potential, such as about 200 V, is applied between the transparent electrodes 12 and the metal electrodes 16, electrons tunnel from one of the  
30           interfaces between the dielectric layers 13,15 and the

phosphor layer 14 into the phosphor layer where they are rapidly accelerated. The phosphor layer 14 typically comprises ZnS doped with Mn. Electrons entering the phosphor layer 14 excite the Mn causing the Mn to emit photons. The photons pass through the first dielectric layer 13, the transparent electrodes 12, and the glass panel 11 to form a visible image.

Although current TFEL panels are satisfactory for some applications, more advanced applications require brighter higher contrast panels, larger panels, and sunlight viewable panels. One approach in attempt to provide adequate panel contrast under high ambient illumination is the use of a circular polarizer filter which reduces ambient reflected light. A circular polarizer filter operates best with a TFEL panel which is very specular. If the specularity of the metal rear aluminum electrodes 16 can be increased, then the efficiency of the circular polarizer filter will also increase.

#### Disclosure of the Invention

An object of the present invention is to reduce the reflection of ambient light and enhance the contrast of a TFEL panel to provide a sunlight viewable TFEL panel.

According to the present invention, the layered structure of a TFEL panel includes a layer of phosphor which is deposited using thermal evaporation at a rate which is at least 50 Angstroms per second to enhance the specularity of the panel.

According to another aspect of the present invention, a display system includes an enhanced specularity TFEL panel and a circular polarizer filter.

When circularly polarized light from the filter strikes a specular surface the direction of the polarization (i.e., either clockwise or counter clockwise) is reversed and this light can no longer pass back through the linear polarizer plate which is an integral part of the circular polarizer filter. Therefore, the greater the specularity of the electroluminescent panel the less reflected light which passes back through the circular polarizer filter and hence the greater the contrast of the display panel.

The enhanced specularity TFEL display of the present invention provides improved display contrast and is comfortably viewable in elevated ambient lighting conditions. These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of a preferred embodiment thereof, as illustrated in the accompanying drawings.

#### Brief Description of the Drawings

Fig. 1 is an illustration of a partial sectional view of the layered structure of an AC thin film electroluminescent (TFEL) panel;

Fig. 2 is an illustration of an enhanced contrast TFEL display system according to the present invention including an increased specularity TFEL panel and a circular polarizer filter;

Fig. 3 is a diagram illustrating ambient light reflected off a prior art TFEL display panel and a circular polarizer filter, and light emitted from an illuminated pixel of the prior art TFEL display panel all directed towards a viewer; and

Fig. 4 is a diagram illustrating ambient light

reflected off the increased specularity display panel  
and the circular polarizer filter both of Fig. 2, and  
light emitted from an illuminated pixel of the  
increased specularity panel all directed towards the  
viewer.

#### Best Mode For Carrying Out The Invention

Referring to Fig. 2, a display system 25 according  
to the present invention includes a highly specular AC  
driven thin film electroluminescent (TFEL) panel 26 and  
a circular polarizer filter 27. The filter 27 has a  
transmission of 30%-40%, preferably about 37%, and an  
anti-reflection coating which provides about a 0.2%  
reflectivity. As known, a circular polarizer filter  
typically includes a linear polarizer and a quarter  
wave plate such that non-polarized light is first  
linearly polarized by the linear polarizer and then  
input to the quarter wave plate which circularly  
polarizes the light.

The layered structure of the highly specular panel  
26 and the panel 10 of Fig. 1 are essentially the same  
and therefore similar layers will retain the same  
numerical designation.

The first step in making a TFEL panel 26 like the  
one shown in Fig. 2 is to deposit a layer of a  
transparent conductor on a suitable glass panel 11.  
The glass panel 11 can be any high temperature glass  
that can withstand the phosphor anneal step described  
below. For example, the glass panel can be a  
borosilicate glass such as Corning 7059 (Corning  
Glassworks, Corning, NY). The transparent conductor  
can be any suitable material that is electrically  
conductive and has a sufficient optical transmittance

for a desired application. For example, the transparent conductor can be ITO, a transition metal semiconductor that comprises about 10 mole percent In, is electrically conductive, and has an optical transmittance of about 85% at a thickness of about 200 nm. The transparent conductor can be any suitable thickness that completely covers the glass and provides the desired conductivity. Glass panels on which a suitable ITO layer has already been deposited can be purchased from Donnelly Corporation (Holland, MI). The remainder of the procedure for making a TFEL display of the present invention will be described in the context of using ITO for the transparent electrodes 12. One skilled in the art will recognize that the procedure for a different transparent conductor would be similar.

ITO electrodes 12 can be formed in the ITO layer by a conventional etch-back method or any other suitable method. For example, parts of the ITO layer that will become the ITO electrodes 12 can be cleaned and covered with an etchant-resistant mask. The etchant-resistant mask can be made by applying a suitable photoresist chemical to the ITO layer, exposing the photoresist chemical to an appropriate wavelength of light, and developing the photoresist chemical. A photoresist chemical that contains 2-ethoxyethyl acetate, n-butyl acetate, xylene, and xylol as primary ingredients is compatible with the present invention. One such photoresist chemical is AZ 4210 Photoresist (Hoechst Celanese Corp., Somerville, NJ). AZ Developer (Hoechst Celanese Corp., Somerville, NJ) is a proprietary developer compatible with AZ 4210 Photoresist. Other commercially available photoresist chemicals and developers also may be compatible with

the present invention. Unmasked parts of the ITO are removed with a suitable etchant to form channels in the ITO layer that define sides of the ITO electrodes 12. The etchant should be capable of removing unmasked ITO without damaging the masked ITO or glass 11 under the unmasked ITO. A suitable ITO etchant can be made by mixing about 1000 ml H<sub>2</sub>O, about 2000 ml HCl, and about 370 g anhydrous FeCl<sub>3</sub>. This etchant is particularly effective when used at about 55°C. The time needed to remove the unmasked ITO depends on the thickness of the ITO layer. For example, a 300 nm thick layer of ITO can be removed in about 2 minutes. The sides of the ITO electrodes 12 should be chamfered, as shown in the figures, to ensure that the first dielectric layer 14 can adequately cover the ITO electrodes. The size and spacing of the ITO electrodes 12 depend on the dimensions of the TFEL display. For example, a typical 12.7 cm (5 in) high by 17.8 cm (7 in) wide display can have ITO electrodes 12 that are about 30 nm thick, about 250  $\mu$ m (10 mils) wide, and spaced about 125  $\mu$ m (5 mils) apart. After etching, the etchant-resistant mask is removed with a suitable stripper, such as one that contains tetramethylammonium hydroxide. AZ 400T Photoresist Stripper (Hoechst Celanese Corp.) is a commercially available product compatible with the AZ 4210 Photoresist. Other commercially available strippers also may be compatible with the present invention.

The dielectric layers 13,15 can be deposited by any suitable conventional method, including sputtering or thermal evaporation. The two dielectric layers 13,15 can be any suitable thickness, such as about 80 nm to about 250 nm thick, and can comprise any



dielectric capable of acting as a capacitor to protect the phosphor layer 14 from excessive currents.

Preferably, the dielectric layers 13,15 will be about 200 nm thick and will comprise SiON. The phosphor layer 14 can be any conventional TFEL phosphor, such as ZnS doped with less than about 1% Mn. According to the present invention the phosphor layer is deposited at a rate which is at least 50 Angstroms per second (e.g., 50-100 Angstroms/sec) in order to provide a smoother layer which enhances the specularity of the panel 26. The phosphor layer 14 can be about 5000-8000 Angstroms thick (i.e., 500-800 nm), and preferably about 5000 Angstroms deposited at a rate of 50 Angstroms/second.

After depositing the phosphor layer 14 followed by the second dielectric layer 15, the panel should be heated to about 500°C for about 1 hour to anneal the phosphor. Annealing causes Mn atoms to migrate to Zn sites in the ZnS lattice from which they can emit photons when excited.

After annealing the phosphor layer 14, the metal electrodes 16 are formed on the second dielectric layer 15 by any suitable method, including etch-back or lift-off. The metal electrodes 16 can be made from any highly conductive metal, such as Al. As with the ITO electrodes 12, the size and spacing of the metal electrodes 16 depend on the dimensions of the display. For example, a typical 12.7 cm (5 in) high by 17.8 cm (7 in) wide TFEL display can have metal electrodes 16 that are about 100 nm thick, about 250  $\mu$ m (10 mils) wide, and spaced about 125  $\mu$ m (5 mils) apart. The metal electrodes 16 should be perpendicular to the ITO electrodes 12 to form a grid.

The present invention is based on the fact that

when circularly polarized light strikes a specular surface, the direction of the circular polarization (i.e., either clockwise or counter clockwise) is reversed and this light can no longer pass back through the linear polarizer plate which is an integral part of a circular polarizer filter. Therefore, the amount of ambient light incident on the surface of the panel which reflects back to the observer can be reduced with a highly specular TFEL panel and a circular polarizer filter. Increasing the specularity of the panel increases the efficiency of the circular polarizer filter and results in improved display contrast since less ambient light is reflected. An example of the improvement in contrast provided by the present invention over the prior art is now in order.

Fig. 3 is a functional illustration of a conventional prior art TFEL display system 30 within an ambient light environment of 2,000 foot-candles (fc) of light. Ambient light 32 strikes the circular polarizer filter 27 at a thirty degree angle taken from a line normal to the plane of the face of the filter 27 resulting in four foot-lamberts (fl) of light 34 being reflected off the face of the filter 27. The ambient light 32 is also reflected off a conventional TFEL panel 35 resulting in about forty-two fl of light 36 being reflected towards the viewer 38. The TFEL panel 35 also provides about 50 fl of light emitted from an illuminated pixel. However, due to the 37% transmission of the filter only about 18.5 fl of light 40 is emitted from the display system 25.

Contrast is the measure the panel's the reflected light 34,36 compared to the emitted light 40, and

contrast is defined as:

$$\text{Contrast} = \frac{\text{panel emitted light} + \text{ambient reflected light}}{\text{ambient reflected light}} \quad \text{[EQ. 1]}$$

5 Since the panel emitted light is 18.5 fl, and the reflected light components from the filter and panel are 4 fl and 42 fl respectively, the contrast of the prior art panel 25 is:

$$\begin{aligned} \text{Prior art panel contrast} &= \frac{18.5 + 42 + 4}{42 + 4} \quad \text{[EQ. 2]} \\ &= 1.4 \end{aligned}$$

Fig. 4 illustrates an enhanced display system 25 of the present invention having the highly specular TFEL panel 26 and the circular polarizer filter 27. Note, the display system of Fig. 4 is substantially the same as the display system in Fig. 3 and therefore where ever possible elements which are essentially the same will retain the same numerical designation. The high specular panel 26 has an active area of 3.5" x 4.7" with 320 ITO column electrodes each 2000 angstroms thick and sputter deposited, and 240 Al row electrodes each 1500 angstroms thick and deposited by thermal evaporation. The phosphor layer is 8000 angstroms thick and deposited by thermal evaporation at a rate of 50 angstroms per second. The dielectric layers were each RF sputtered 2000 angstroms thick SiON. The display system 25 is within an ambient lighting environment of 2000 fc, which results in four fl of reflected light 34 off the filter 27 front surface. The ambient light 32 is also reflected off the highly specular TFEL panel 26 with a

net result that only 4.4 fl of reflected light 42 passes through the circular polarizer filter. Attention is drawn to the fact that the reflected light 36 (Fig. 3) from the prior art TFEL panel 35 was 42 fl in comparison to only 4.4 fl of reflected light 42 (Fig. 4) from the highly specular TFEL panel 26 of the present invention. As a result, substituting the numbers associated with the enhanced display system 25 into Eq. 1 results in a display contrast of:

$$\begin{aligned} \text{enhanced specularity} &= \frac{18.5 + 4 + 4.4}{4 + 4.4} \\ \text{panel contrast} & \quad \quad \quad \text{[Eq. 3]} \\ &= 3.2 \end{aligned}$$

Therefore, the present invention provides about a 2-to-1 improvement in contrast over the conventional specular display panel of Fig. 3. In addition since the TFEL display panel of the present invention has increased specularity it exhibits a diffuse reflectance on the order of only 2%, whereas the prior art panels exhibit diffuse reflectance of 15-20%.

The contrast improvement associated with the enhanced display system 25 is primarily due to the improvement in the specularity of the TFEL panel 26 and the resulting increase in efficiency which the circular polarizer filter provides. Enhancing the specularity of the TFEL panel 26 increases the efficiency of the circular polarizer filter 27 and results in improved display contrast since less light is reflected.

Incidentally it will be appreciated that if the display system of the present invention will be used outside for prolonged periods, an ultraviolet (UV) filter should be placed in front of the circular

polarizer 27 to ensure that UV light does not destroy the polarizing properties of the circular filter.

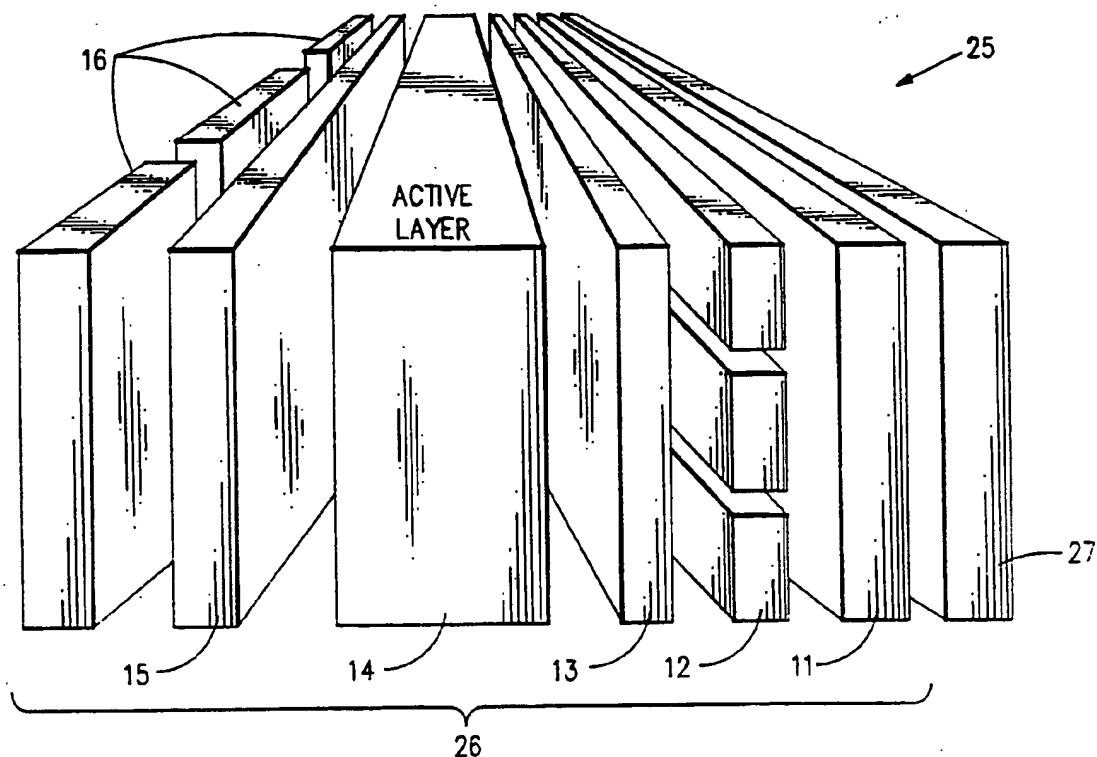
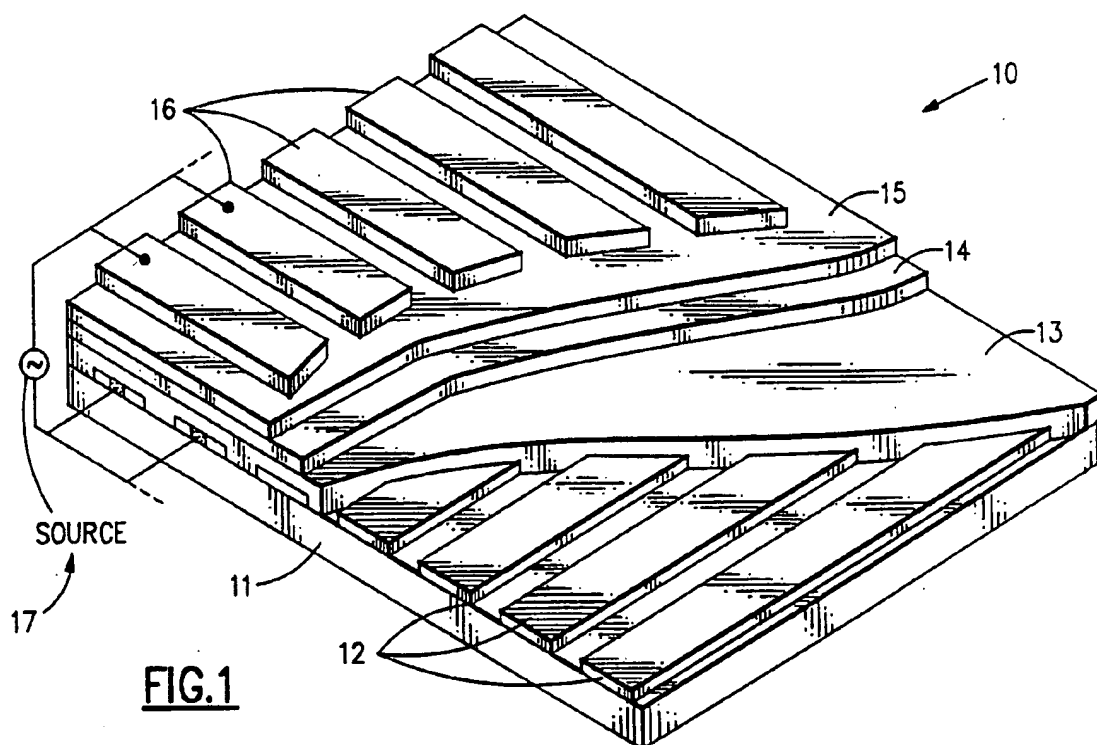
Although the invention has been shown and described with respect to a preferred embodiment thereof, it  
5 should be understood by those skilled in the art that various other changes, omissions, and additions may be made to the embodiments disclosed herein, without departing from the spirit and scope of the present invention.

10 We claim:

## Claims

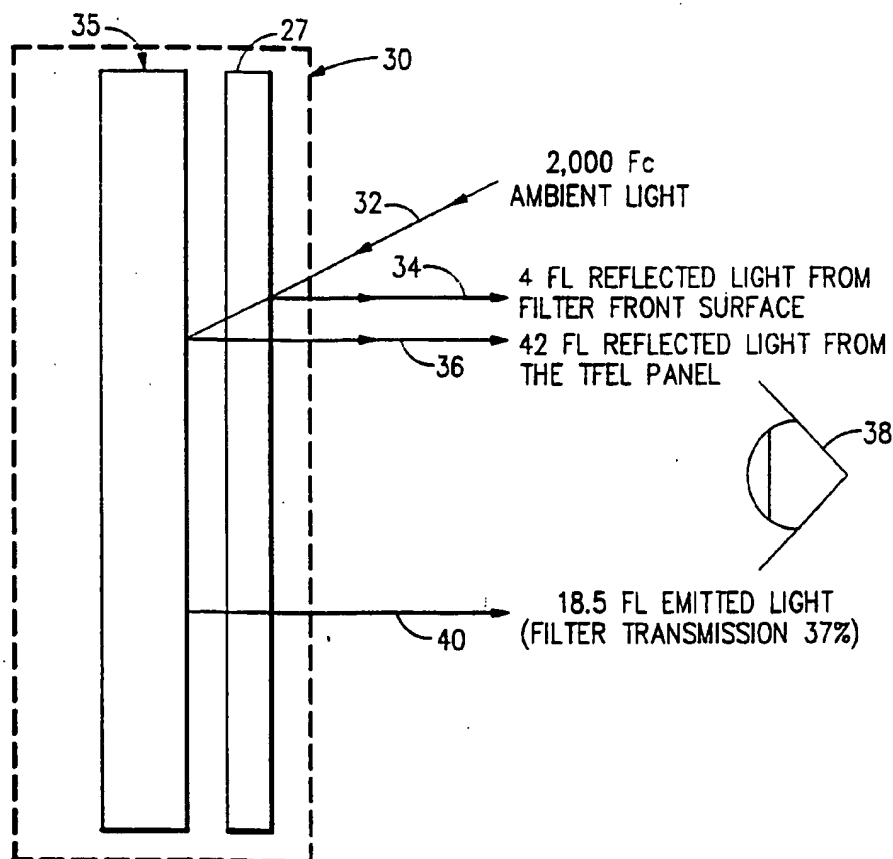
- 1     1.    A high contrast thin film electroluminescent  
2     display, comprising:  
3         a) an electroluminescent panel including  
4             a glass substrate;  
5             a plurality of parallel transparent electrodes  
6     deposited on said glass substrate;  
7             a first dielectric layer deposited on said  
8     plurality of transparent electrodes and exposed portions  
9     of said glass substrate to form a smooth planar surface;  
10            a layer of phosphorus material deposited on  
11     said smooth planar surface of said first dielectric  
12     layer;  
13            a second dielectric layer deposited on said  
14     layer of phosphorus material;  
15            a plurality of metal electrodes each deposited  
16     in parallel over said second layer of dielectric  
17     material; and  
18         b) a circular polarizer filter positioned adjacent  
19     to said glass substrate such that said  
20     electroluminescent panel is viewed through said  
21     polarizer filter.
- 1     2.    The display panel according to claim 1, wherein  
2     said layer of phosphorous material is deposited at a  
3     rate which is at least fifty angstroms per second.
- 1     3.    The display panel according to claim 1 wherein said  
2     layer of phosphorus material comprises ZnS doped with  
3     about 1% Mn which is deposited at a rate which is at  
4     least fifty angstroms per second.

1        4.    A method of constructing an electroluminescent  
2        panel, comprising the steps of depositing a transparent  
3        conductive material on a glass substrate to provide  
4        plurality of column electrodes, followed by depositing a  
5        first layer of dielectric material over the transparent  
6        conductive material and the exposed portions of the  
7        glass substrate, followed next by depositing a layer of  
8        phosphorous material, next depositing a second layer of  
9        dielectric material over said layer of phoshor, followed  
10       last by depositing a plurality of metal row electrodes  
11       over said second layer of dielectric material, wherein  
12       the improvement comprises the step of  
13              depositing said phosphorous material at a rate of  
14       at least 50 Angstroms per second by thermal evaporation.

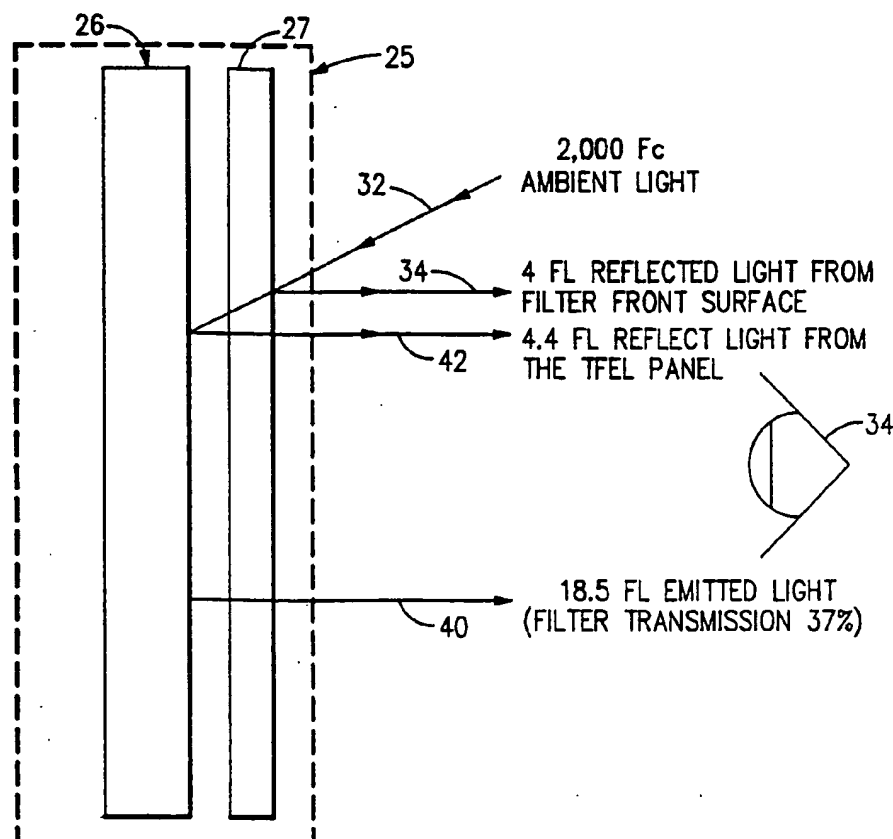




**FIG.3**  
Prior Art



**FIG.4**



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 93/12233

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 5 H05B33/22 H05B33/12 H05B33/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB,A,1 389 737 (GEC) 9 April 1975 see the whole document ---	1
Y	DATABASE INSPEC INSTITUTE OF ELECTRICAL ENGINEERS, STEVENAGE, GB Inspec No. 2005357 April 1982, see abstract & SOVIET JOURNAL OF OPTICAL TECHNOLOGY vol. 49, no. 4, April 1982, USA pages 239 - 241 S.S.SAVKO & AL 'a circular polarizer...' --- -/--	1

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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# INTERNATIONAL SEARCH REPORT

Inter. Appl. No.

PCT/US 93/12233

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	<p>DATABASE WPI  Section Ch,  Derwent Publications Ltd., London, GB;  Class L03, AN 93-164905  &amp; JP,A,5 098 421 (FUJI ELECTRIC) 20 April  1993  see abstract</p> <p style="text-align: center;">---</p>	2,3
A	<p>DATABASE WPI  Section Ch,  Derwent Publications Ltd., London, GB;  Class L03, AN 88-081951  &amp; JP,A,63 035 765 (KOHJIN) 16 February  1988  see abstract</p> <p style="text-align: center;">-----</p>	2,4

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 93/12233

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A-1389737	09-04-75	NONE	

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